RISK*e*Learning

Nanotechnology – Applications and Implications for Superfund

April 19, 2007
Session 4:
"Nanotechnology – Superfund Site Remediation"
Marti Otto, EPA OSRTI
Mary Logan, RPM, EPA Region 5

Organizing Committee:

SBRP/NIEHS	EPA		MDB
William Suk	Michael Gill	Nora Savage	Maureen Avakian
Heather Henry	Jayne Michaud	Barbara Walton	Larry Whitson
Claudia Thompson	Warren Layne	Randall Wentsel	Larry Reed
Beth Anderson	Marian Olsen	Mitch Lasat	
Kathy Ahlmark	Charles Maurice	Martha Otto	

Nanoscale Zero-Valent Iron Field-Scale and Full-Scale Studies

Risk e-Learning Internet Seminar Series
"Nanotechnology: Applications and Implications
for Superfund."

April 19, 2007

Marti Otto
Technology Innovation and Field Services Division
Office of Superfund Remediation and Technology Innovation
U.S. Environmental Protection Agency
Otto.martha@epa.gov

Outline

- Background
- Field-scale studies
  - Tuboscope Site, AK
  - Launch Complex 34, FL
  - NAS Jacksonville, FL
  - NAES Lakehurst, NJ
- Outreach and Publications

Nanotechnology shows great promise for improved sensors. The sensors can lead to improved monitoring and detection capabilities that allow for real-time, accurate sensing of many compounds simultaneously at extremely low concentrations frequently in hostile environments[BK1].

Treatment involves cleaning up waste streams of contaminants, particularly those substances that are highly toxic, persistent within the environment, or difficult to treat. Nanotechnology holds promise for cost-effective, specific, and rapid solutions for treatment of contaminants[BK2].

Remediation addresses problems brought about by prior technologies and past practices. Cleanup of contaminated sites using nanotechnology is one of the initial successes in nano tech applications to the environment. Researchers are developing cost-effective technologies that enable both rapid and effective cleanup of recalcitrant compounds, particularly those located in inaccessible areas[BK3].

There are two aspects of nanotechnology applications in green manufacturing. The first involves using nanotechnology itself to eliminate the generation of waste products and streams by designing in pollution prevention at the source. The second aspect involves the manufacture of nano materials themselves in a benign manner. Both of these involve use of environmentally friendly starting materials and solvents, improved catalysts, and significantly reduced consumption of energy in the manufacturing process[BK4].

Background: OSWER and TIFSD

Office of Solid Waste and Emergency Response

http://yosemite.epa.gov/r10/cleanup.nsf/sites/CleanCare?OpenDocument

- **Develops hazardous waste standards and regulations (RCRA)**
- **Regulates land disposal and waste (RCRA)**
- **Cleans up contaminated property and prepares it for reuse (Brownfields, RCRA, Superfund)**
- **Helps to prevent, plans for, and responds to emergencies (Oil spills, Chemical releases, Decontamination)**
- **Promotes innovative technologies to assess and clean up contaminated waste sites, soil, and groundwater (Technology Innovation)**

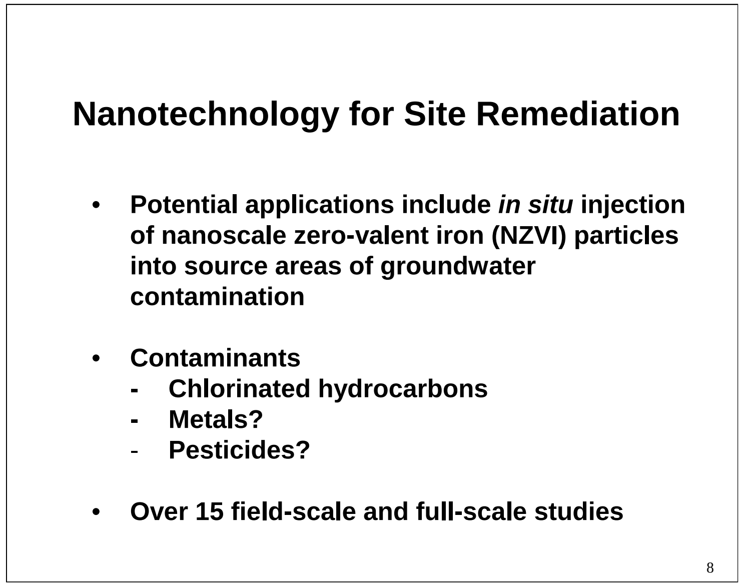
Technology Innovation and Field Services Division

- Provides information about characterization and treatment technologies (Clu-in, TechDirect, TechTrends, Case Studies, Technical Overviews)
- Advocates more effective, less costly technologies

http://www.epa.gov

- Provides national leadership for the delivery of analytical chemistry services for regional and state decision makers to use at Superfund and Brownfield sites
- Environmental Response Team (ERT) provides technical assistance and science support to environmental emergencies

Background:
Nanotechnology for Site Remediation



Nanotechnology shows great promise for improved sensors. The sensors can lead to improved monitoring and detection capabilities that allow for real-time, accurate sensing of many compounds simultaneously at extremely low concentrations frequently in hostile environments[BK1].

Treatment involves cleaning up waste streams of contaminants, particularly those substances that are highly toxic, persistent within the environment, or difficult to treat. Nanotechnology holds promise for cost-effective, specific, and rapid solutions for treatment of contaminants[BK2].

Remediation addresses problems brought about by prior technologies and past practices. Cleanup of contaminated sites using nanotechnology is one of the initial successes in nano tech applications to the environment. Researchers are developing cost-effective technologies that enable both rapid and effective cleanup of recalcitrant compounds, particularly those located in inaccessible areas[BK3].

There are two aspects of nanotechnology applications in green manufacturing. The first involves using nanotechnology itself to eliminate the generation of waste products and streams by designing in pollution prevention at the source. The second aspect involves the manufacture of nano materials themselves in a benign manner. Both of these involve use of environmentally friendly starting materials and solvents, improved catalysts, and significantly reduced consumption of energy in the manufacturing process[BK4].

Field Scale Studies

- 2 EPA sites with field studies in 2006
  - Tuboscope site, Alaska
  - Nease Chemical, Ohio
- 2 field studies with emulsified nanoscale zero-valent iron (EZVI)
  - NASA's Launch Complex 34, FL
  - Parris Island, SC
- Majority of field studies
  - Trichloroethene (TCE), trichloroethane (TCA), degradation products
  - Gravity-feed or low pressure injection
  - Source zone remediation

Tuboscope Site
BP/Prudhoe Bay, Alaska

Tuboscope Site
BP/Prudhoe Bay
North Slope, Alaska

Tuboscope Site
BP/Prudhoe Bay
North Slope, Alaska

- **Cleaned pipes used in oil well construction from 1978 to 1982**

- **Contaminants**
  - **Trichloroethane (TCA)**
  - **Diesel fuel**
  - **Lead**

Tuboscope Site

North Slope, Alaska

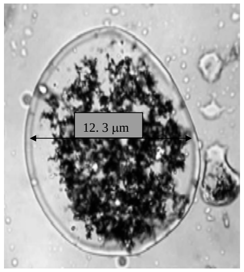
- Pilot test: injection of NZVI
- Objectives/Goals
  - Reduce the concentrations of TCA and diesel fuel contaminants
  - Reduce the mobility of lead at the site
- Field Test conducted August 2006
- First round of sampling: September 2006
- More information: hedeen.roberta@epa.gov

Launch Complex 34, FL

Launch Complex 34

- Used as launch site for Saturn rockets from 1960 to 1968
- Rocket engines cleaned on launch pad using chlorinated VOCs, including TCE
- DNAPL (primarily TCE) present in subsurface
- EZVI demonstration conducted beneath the Engineering Support Building

Properties of Emulsified Zero-Valent Iron



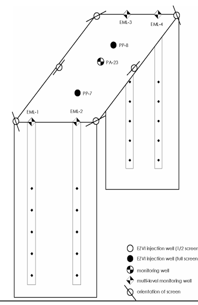
Jacqueline Quinn, NASA

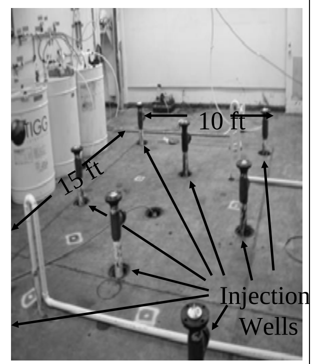
- **Oil membrane is hydrophobic and miscible with DNAPL**
- **Abiotic degradation by ZVI**
- **Biodegradation enhanced by vegetable oil and surfactant components of EZVI**

EZVI Injection Set-Up

- EZVI injected in 8 injection wells
- Injection wells along edge of plot directed inwards
- Injection wells in center were fully screened
- Injection at 2 discrete depth intervals in each well

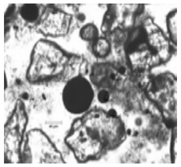
Slide: Jacqueline Quinn, NASA





Soil Core Samples

Jacqueline Quinn, NASA



Soil core sample

Results

- Significant reduction (57 to 100%) of TCE in target depths within 5 months
- Significant additional reduction of TCE in groundwater samples collected 18 months after injection
- Data suggest longer-term TCE reduction due to biodegradation
- Subsequent fieldwork indicates that better distribution of EZVI may be achieved using pneumatic fracturing or direct push rather than pressure pulse injection method

NAS Jacksonville, FL

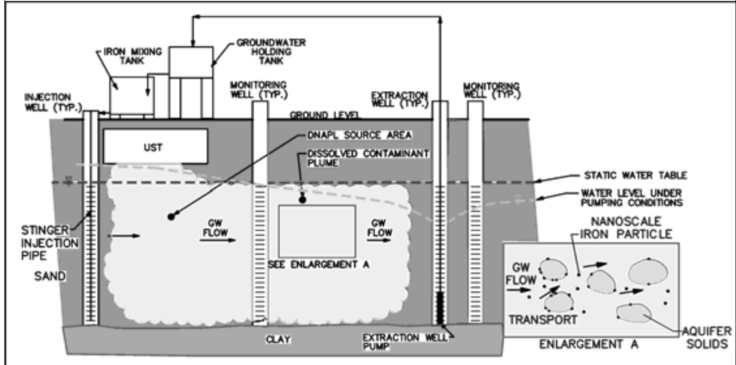
NAS Jacksonville

- Former underground storage tanks
- Source area contaminants: TCE, PCE, 1,1,1-TCA, and 1,2-DCE
- CERCLA cleanup
- Groundwater monitoring under RCRA

NZVI Injection

- Gravity Feed
- 10 injection points
- 300 lb bimetallic nanoparticles (BNP)
  (99.9 % Fe, 0.1 % Pd and polymer support)

Technology Implementation



Nancy Ruiz, USNavy

300 lb BNP (99.9 % Fe, 0.1 % Pd and polymer support)

- Initial direct-push technology injection (40 lb)
- 1st recirculation event (110 lb) – 2 to 4.5 g/L
- 2nd recirculation event (150 lb) – 4.5 g/L

Injection at 10 locations; known hot spots

Recirculation system – downgradient groundwater

NZVI continuously added to recirculation water

Gravity flow injection

Results/Conclusions

- NZVI significantly reduced dissolved TCE levels in several source zone wells
- Some increases in cis-1,2-DCE and 1,1-DCA
- Did not achieve strong reducing conditions to generate substantial abiotic degradation of TCE
  - Potentially deactivated NZVI due to mixing with oxygenated water, or
  - Insufficient iron may have been injected

NAES Lakehurst, NJ

NAES Lakehurst, NJ

- Pilot-scale study in 2003
- Full-scale work in 2005 and 2006
- PCE, TCE, TCA, *cis*-DCE, VC
- Largest amount of contamination 45 to 60 ft below groundwater table

NAES Lakehurst, NJ

Full-Scale Project

- **November 2005: Phase I (2300 lb nanoscale bimetallic particles)**
- **January 2006: Phase II (500 lb nanoscale bimetallic particles)**
- **Injection method: direct push wells**
- **Remedial objective: to attain NJ groundwater quality standards using a combination of NZVI and monitored natural attenuation**

Full-Scale Project

- Media treated
  - Groundwater
  - Soil
- Initial concentrations up to 360 ppb chlorinated VOCs
- Final concentrations: TBD
- Groundwater quality standards have been obtained for some monitoring wells
- Monitoring continues.

Summary of Navy's Conclusions

- NZVI is a promising technology for source zone treatment
- Inject sufficient iron to create strongly reducing environment, which is essential for success
- Take care to not deactivate NZVI during storage or mixing
- Short-term performance monitoring can be misleading. Long-term monitoring of treatment zone until ORP levels have returned to pre-treatment levels is essential.
- Cost and Performance Report: Nanoscale Zero-Valent Iron Technologies for Source Remediation available on http://www.clu-in.org
- More information: Project Manager at (805) 982-1155

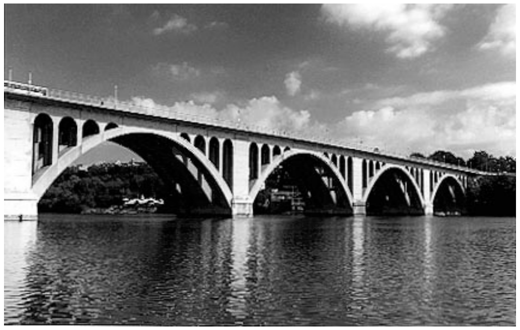
Outreach and Publications

- October 2005 Workshop on Nanotechnology for Site Remediation
  - Held October 20-21, 2005, in Washington, D.C.
  - Proceedings and presentations:
    http://www.frtr.gov/nano

- Nanotechnology and OSWER: New Opportunities and Challenges
  - Held July 12-13, 2006, in Washington, D.C.
  - Presentations:
    http://esc.syrres.com/nanotech/

Outreach and Publications, Cont.

- Issues area on CLU-IN website
  http://clu-in.org/nano
- Upcoming TIFSD products on nanotechnology
  - Spreadsheet of field tests
    - Cost and performance
    - Media/contaminants
    - Technology/vendor information
    - Points of contact
  - Fact sheet on nanotechnology for site remediation



Marti Otto
Technology Assessment Branch
Technology Innovation and Field Services Division
703.603.8853
Otto.martha@epa.gov

Nease Chemical Site Nanotechnology Update

Risk e-Learning Internet Seminar Series
"Nanotechnology: Applications and Implications for Superfund"

Mary Logan
U.S. EPA, Region 5
April 19, 2007

Objectives

- Provide brief site description
- Brief overview of selected remedy for soil, source areas and groundwater
  - Considerations that led to selection of nanotechnology for groundwater clean up
- Discuss status of groundwater remediation by nanotechnology at the Nease site
  - Preliminary pilot study results

Acknowledgements

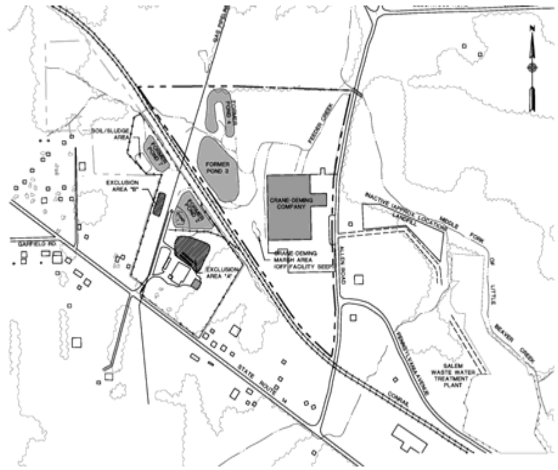
- Rutgers Organics Corporation – current site owner, has agreed to conduct work
- Golder Associates – primary contractor for Rutgers, is performing and/or overseeing the work
  - Special thanks for use of figures and pictures
- Ohio EPA – partner oversight agency and technical support
- EPA's technical support – Region 5 and ORD

Nease Chemical Superfund Site Overview

Site Background

- Nease facility
  - Former chemical manufacturing plant
  - Operated from 1961 – 1973
  - Spills and on-site waste disposal
- The remedy for soil, source areas and groundwater was selected by EPA in 2005
  - More than 150 contaminants identified
  - Primary site contaminants include:
    - Mirex in soil up to 2,080 ppm
    - VOCs in groundwater over 100 ppm
- A future remedy will address mirex in sediment and floodplains

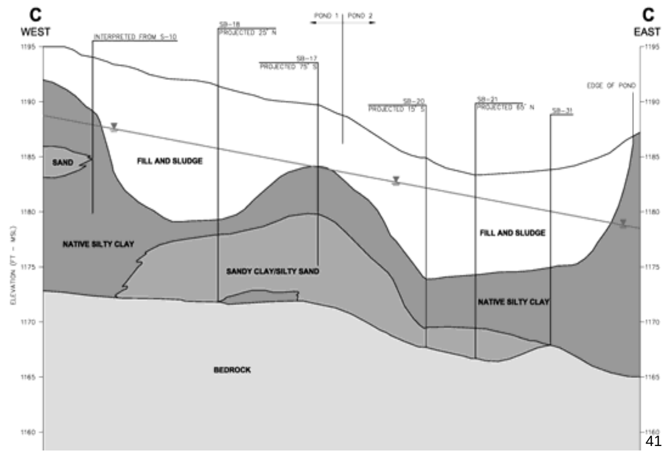
Nease Chemical Superfund Site



Summary of Source Area and Groundwater Contamination

- Hydrogeologic units: overburden; transition bedrock; Middle Kittanning Sandstone bedrock
  - Units are hydraulically connected
  - Depth to groundwater – a few feet to ~ 9 ft.
- Former Ponds 1 & 2 → primary source of contamination to groundwater
  - ~ 50,000 CY waste/fill and underlying soil
  - Waste/fill in ponds is generally below the water table
  - Maximum pond waste concentration: VOCs > 50,000 ppm; SVOCs ~ 11,000 ppm; pesticides ~ 1,000 ppm; NAPL is found in waste and till
- Primary groundwater contaminants – chlorinated ethanes and ethenes, benzene, chlorobenzene

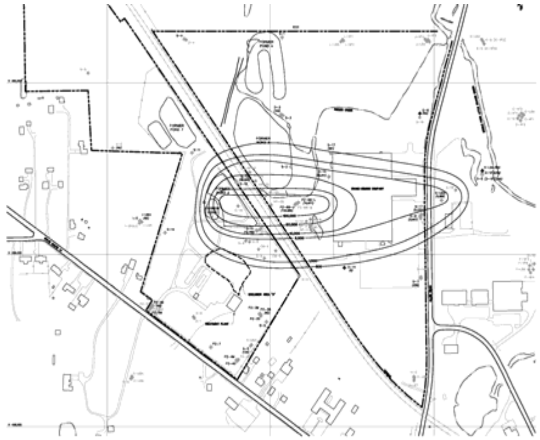
Cross Section – Former Ponds 1 and 2



Bedrock Groundwater

- Middle Kittanning Sandstone
  - Thickness - 21 to 53 ft.
  - Velocity ~ 65 to 160 ft/yr
- Bedrock is fractured
  - Flow primarily through bedding plane partings
- DNAPL is present
- Plume length ~ 1650 ft.
- Max. total VOCs > 100 ppm
- Natural attenuation seems to be occurring

Groundwater Contaminant Contours
Total VOCs – Bedrock July 2003



Operable Unit 2 Selected Remedy

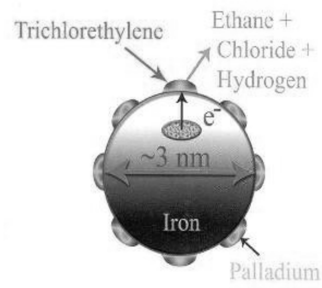
- Former Ponds 1 and 2 → in-situ treatment by soil mixing/air stripping, stabilization and solidification.
- Ponds and soil → covered/capped.
  - Includes Ponds 1 & 2 after treatment
- Shallow eastern groundwater → captured in a trench, pumped above ground, treated on site.
- Bedrock groundwater → treated by injection of nanoscale zero-valent iron (NZVI).
  - Treatment of plume core, MNA downgradient
  - NZVI treatment may be coupled with enhanced biological treatment
  - Pre-design data suggests that the approach for the southern area groundwater must be reconsidered
- Long-term O&M, institutional controls.

Conceptual Layout of Remedy

NZVI – Remedy Evaluation Considerations

What is NZVI?

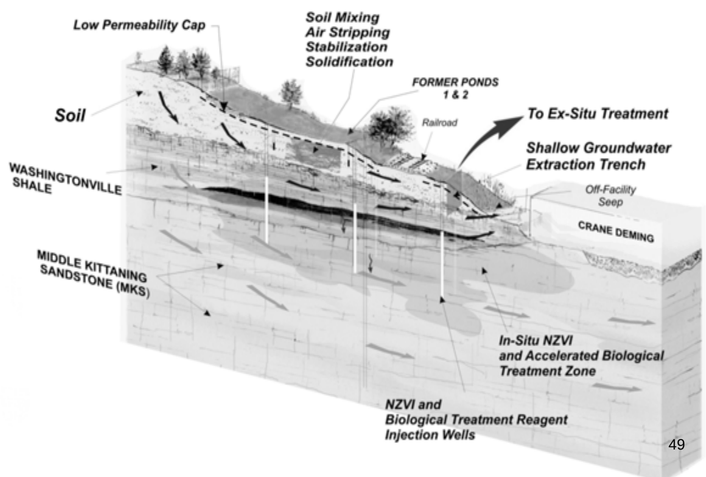
- 1 – 100 nanometer sized iron particles
  - A human hair is 500 to 5000 times wider
  - Large surface area compared to volume
- NZVI is very reactive
  - Contaminants are destroyed by a reaction similar to rusting
  - Non-toxic by-products are formed
- Iron can be enhanced
  - Reactive catalyst
  - Coatings



How Does NZVI Work?

- An iron-water slurry is injected through wells into the contaminated aquifer.
  - Intended to diffuse/flow with groundwater
    - Need to spread the iron
  - Goal → in-situ treatment of contaminants
- Contaminants are rapidly destroyed by oxidation-reduction reactions.
- With time, iron particles partially settle out and reactivity declines.

Conceptual Diagram of Nease Site Remedy



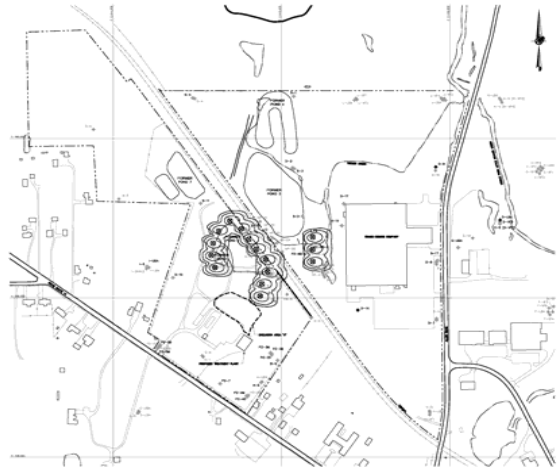
FS Analysis - Considerations

- Types of contaminants and the ability of NZVI to treat the contaminants of concern
  - Ability to combine NZVI with other approaches for recalcitrant contaminants
- Existing conditions
  - Site hydrogeology
  - Groundwater geochemistry
- Source control
- Underground injection requirements
  - Likely to be ARARs
- Cost

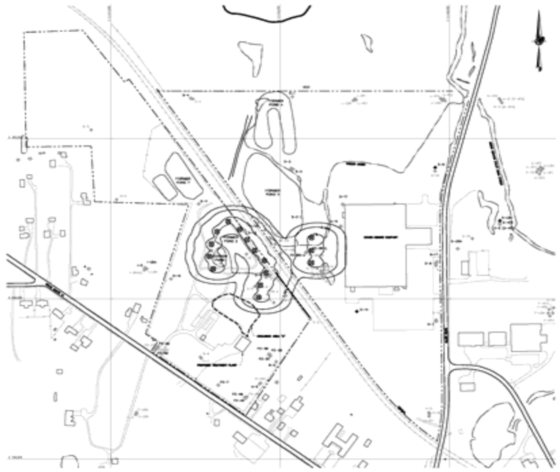
FS Analysis – Considerations (cont.)

- Estimate number of injection wells
  - Radius of influence of treatment zone to determine injection well spacing
    - Simple 2D modeling
- Estimate frequency and timing of injections
  - Calculate NZVI mass requirements
    - Simple stoichiometric calculations
    - Additional iron to account for waste
  - Rebound can occur as NZVI is used up
    - Addressed by multiple injections

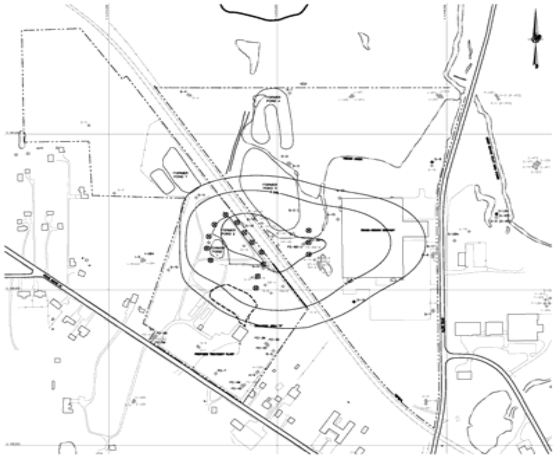
FS Projections - NZVI Area of Influence After a Few Days



FS Projections - NZVI Area of Influence After a Few Weeks



FS Projections - NZVI Area of Influence After a Few Months



Why NZVI at the Nease Site?

- Contaminants – generally treatable
  - Chlorinated ethenes, ethanes
- Favorable geochemical conditions
  - Low dissolved oxygen concentrations
  - Relatively low nitrate/nitrite and sulfate
- Unfavorable conditions for other options
  - Fractured bedrock (favorable for NZVI)
  - DNAPL
- Desire to maintain/enhance existing site conditions that support natural attenuation
  - Strongly reducing conditions created by NZVI
    - Favorable for anaerobic bacteria that may help degrade chemicals not treated by the iron
- Relatively low cost

Nease Chemical Site
NZVI Treatability Study

NZVI Treatability Study

- NZVI treatability study is being conducted as part of the pre-design investigation
- NZVI study has two phases
  - Bench scale study
  - Field pilot test
- Final Remedial Design will be based on results
- Bench study started in July 2006
- Field pilot started in November 2006

Bench Scale Study

Bench Study - Objectives

- Assess effectiveness of NZVI for treatment of chlorinated VOCs
- Determine effects (if any) of NZVI on non-chlorinated VOCs
- Evaluate by-product generation
- Determine optimal formulation and dosage
- Evaluate site-specific geochemical influences on treatment effectiveness
- Determine the longevity of NZVI

Bench Study - Approach

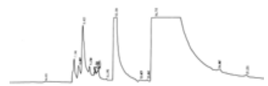
- Highly contaminated groundwater collected
  - Baseline analysis
- Four different iron materials tested
  - Mechanically produced or chemically precipitated
  - With and without palladium catalyst
- Jar tests for rate and effectiveness of a range of NZVI concentrations/formulations
  - 0, 0.05, 0.1, 0.5, 1, 2, 5, and 10 g/L
- Jar tests to assess the influence of site soils
- Capacity tests → effectiveness of iron to treat re-contaminated samples

Bench Test Procedures

Water Samples from the Site

Batch Reactors

Gas Chromatograph



Before

After

Baseline Contaminant Levels

Contaminant	Result (ug/L)
Benzene	7,000
1,2-Dichlorobenzene	15,000
cis-1,2-Dichloroethene	11,000
trans-1,2-Dichloroethene	2,200 J
Methylene chloride	2,100 J
1,1,2,2-Tetrachloroethane	2,300 J
Tetrachloroethene (PCE)	82,000
Toluene	1,500 J
Trichloroethene (TCE)	21,000

Bench Study - Primary Results

- Mechanically produced NZVI with 1% palladium at 2 g/L recommended formulation
- Chemically produced iron showed slightly better performance than mechanically produced, but both were adequate
- NZVI without palladium showed only partial treatment within 2 weeks
- No chlorinated by-products were detected
- Benzene was not adequately treated and was produced as a by-product by reduction of 1,2-dichlorobenzene
- Site soils did not seem to inhibit treatment

Bench test reductions within 2 weeks using mechanically produced NZVI with 1% palladium at 2 g/L.

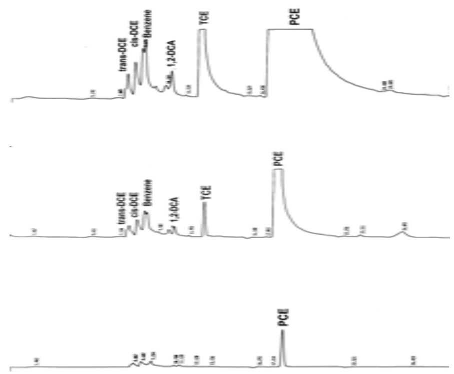
Contaminant	Reduction
PCE	98%
TCE	99%
cis-1,2-DCE	97%
trans-1,2-DCE	>99.9%
1,2-DCA	99%
1,2-Dichlorobenzene	“complete”

Nease Bench Test - GC Spectra

T = 0

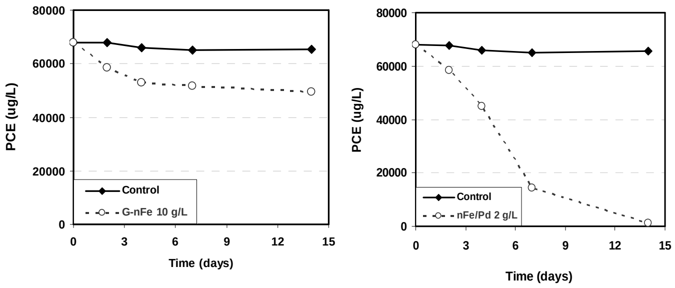
T = 2 days

T = 14 days



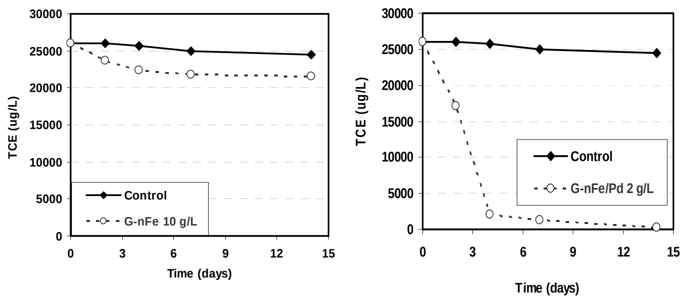
2 g NanoFe/Pd per liter groundwater

Nease Bench Test - PCE Degradation



10 g NanoFe or 2 g NanoFe/Pd per liter groundwater
Pd concentration was 1%wt
PCE initial concentration 68000 ug/L

Nease Bench Test - TCE Degradation



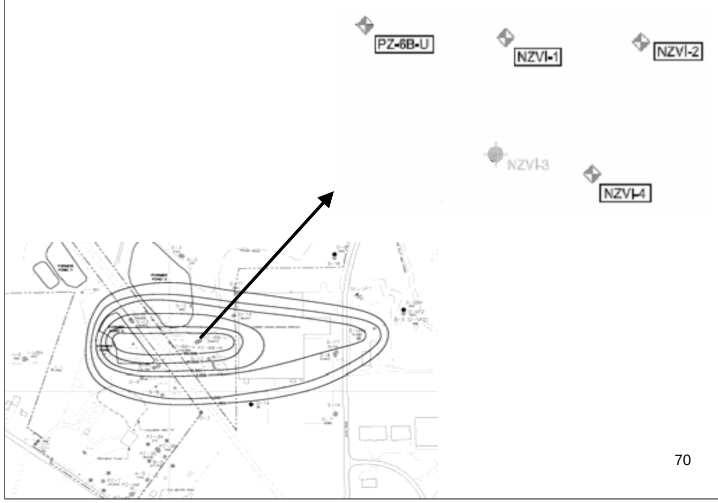
10 g NanoFe or 2 g NanoFe/Pd per liter groundwater
Pd concentration was 1%wt
TCE initial concentration 26000 ug/L

Field Pilot Test

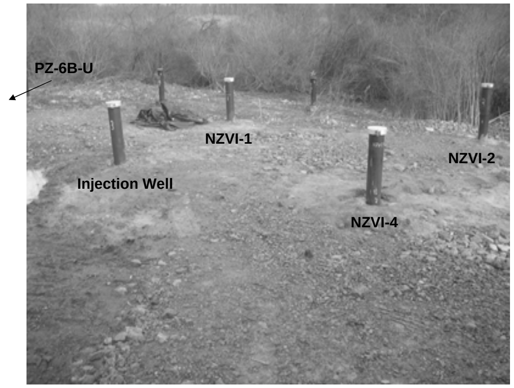
Field Pilot Test - Objectives

- Verify laboratory results
- Evaluate treatment under field conditions
  - Confirm in-situ treatment effectiveness
  - Evaluate geochemical changes in the aquifer
- Support the remedial design
  - Evaluate rate of transport/dispersion of NZVI
  - Assess size of effective treatment zone

Study Area and Pilot Study Wells



Field Pilot Well Array



Additional Aquifer Testing

- Slug tests performed on wells
  - Some wells in zones of lower hydraulic conductivity
- Tracer testing was conducted using saline
  - Demonstrated interconnection of wells
  - Provided data on time for saline to reach wells and time for peak concentrations to be seen
- Tests provided estimates of potential injection rates and volume
- Resulted in a new well and the planned injection well was changed

Field Pilot Test – Approach

- NZVI brought to site as parent slurry, mixed in batches
- Parent slurry mixed with potable water to provide injected slurry
  - Injected concentration 10 g/L
  - Contained powdered soy (patent pending) as an organic dispersant
    - 20% by weight of NZVI
  - Most batches contained palladium
    - 1% by weight of NZVI
  - Last few injections were iron without palladium

Mixing NZVI Injection Slurry

Field Pilot Test – Approach (cont.)

- Injection of NZVI slurry
  - Injection well
    - Work plan: Planned to use PZ-6B-U
    - Actual: Used well NZVI-3
  - Injection rate
    - Work plan: Planned at 2 gpm or higher
    - Actual: 0.15 – 1.54 gpm
  - Injection time
    - Work plan: Planned over 3 – 4 days
    - Actual: Took about 22 days
  - NZVI mass
    - Work plan: Planned to inject 100 kg (75% with palladium)
    - Actual: Injected 100 kg (~87% with palladium)
  - Injection volume
    - Work plan: Planned on 2,600 to 3,500 gallons of slurry
    - Actual: 2,665 gallons

Summary of NZVI Injections

Date	Injection Method	Injection Pressure (psi)	Average Injection Rate (gallons per minute (GPM)	NZVI/Pd (KG)	NZVI (KG)	NZVI Slurry (gallons)
11/28/2006	Gravity w/ pumping - open system	NA	0.6	5		132
11/29/2006	Gravity w/ pumping - open system[1]	NA	0.9	6		159
11/30/2006	Gravity w/ pumping - open system[2]	NA	0.5	1.5		40
12/1/2006	Gravity w/ pumping - open system	NA	<0.5	3		79
12/4/2006	Gravity - open system[3]	NA	1.25	1.9		50
12/5/2006	Gravity - open system[3]	NA	0.3	3.4		90
12/6/2006	Gravity - closed system[4]	4	1	1.9		50
12/7/2006	Gravity - closed system[5]	NA	0.46	2.6		70
12/8/2006	Pressure Injection - closed system	11	2	4.5		120
12/9/2006	Pressure Injection - closed system[6]	8	1.54	6.4		170
12/10/2006	Pressure Injection - closed system[6]	8	1.5	1.1		30
12/11/2006	Pressure Injection - closed system[6]	6	0.77	6.4		170
12/12/2006	Pressure Injection - closed system[7]	5 to 19	0.6	4.3		115
12/13/2006	Pressure Injection - closed system	5 to 25	0.7	5.5		145
12/14/2006	Pressure Injection - closed system[8]	17	0.36	4.9		130
12/15/2006	Gravity - closed system[4] (over night)	NA	0.07	2.07		55
12/15/2006	Pressure Injection - closed system[8]	17	0.44	4.54		120
12/16/2006	Pressure Injection - closed system[9]	17-10	0.15	1.89		50
12/18/2006	Pressure Injection - closed system[9]	3-10	1.3	3		80
12/19/2006	Pressure Injection - closed system[10]	7-12	0.95	11.72		310
12/20/2006	Pressure Injection - closed system	10	0.73	5.67		150
		14	0.60		2.27	60
12/21/2006	Pressure Injection - closed system	14	0.69		10.96	290
			TOTAL	**87.4**	**13.2**	**2,665**

NZVI Injection

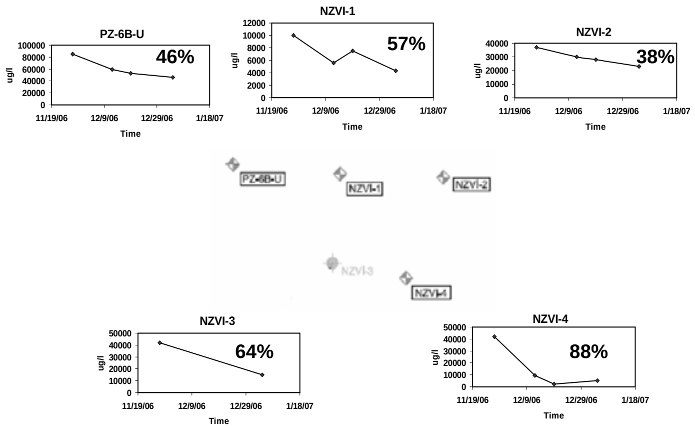
Pressure injection system allows for injection under pressure in a closed system.

Field Pilot Test – Monitoring

Downhole electronic dataloggers

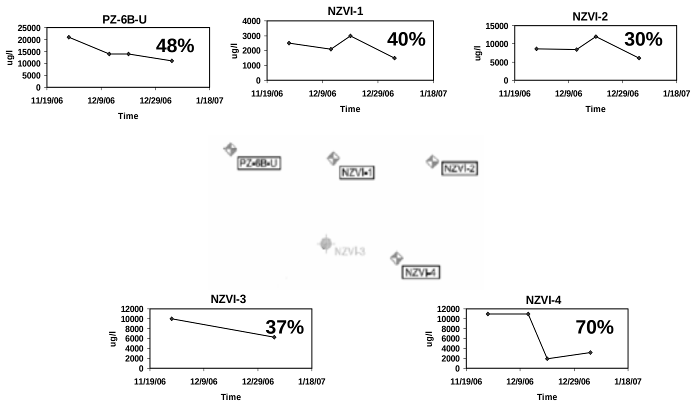
- Continuously
- Geochemical parameters – conductivity, pH, ORP, DO, temperature, potentiometric head

- Baseline chemical monitoring
- Post-injection chemical monitoring
  - 1, 2, 4, 8, and 12 weeks post-injection planned
    - "1 week" sample taken about 14 days after injections started
  - VOCs – all sample events
  - SVOCs and natural attenuation parameters – select sample events



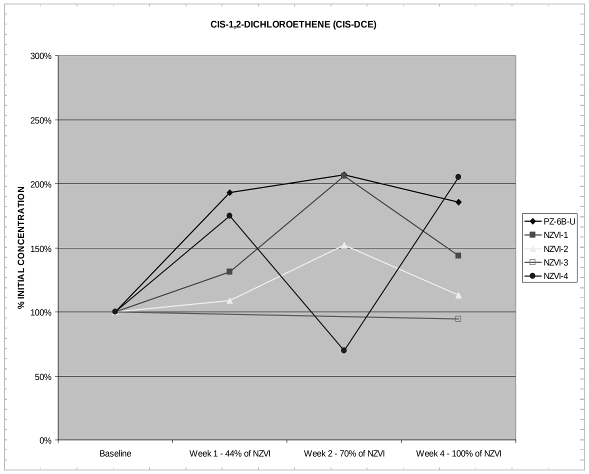
PCE Reduction Over Time

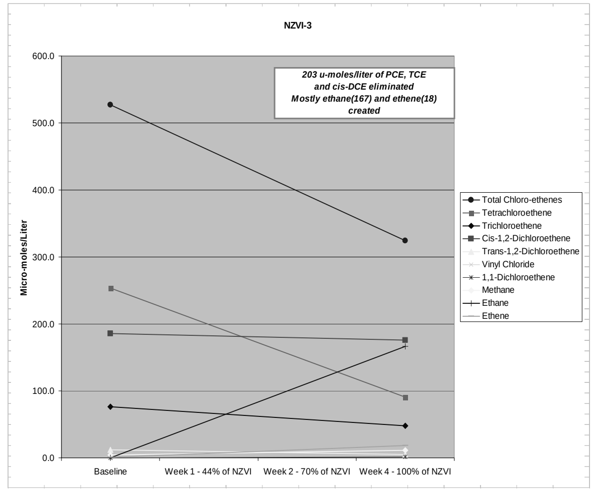
WEEK 4

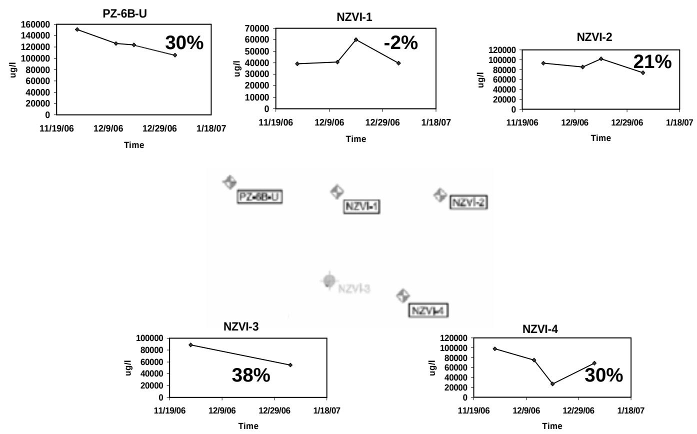


TCE Reduction Over Time

WEEK 4


CIS-1,2-DICHLOROETHENE (CIS-DCE)
% INITIAL CONCENTRATION
300%
250%
200%
150%
100%
50%
0%
Baseline
Week 1 - 44% of NZVI
Week 2 - 70% of NZVI
Week 4 - 100% of NZVI
PZ-6B-U
NZVI-1
NZVI-2
NZVI-3
NZVI-4


NZVI-3
203 u-moles/liter of PCE, TCE and cis-DCE eliminated Mostly ethane(167) and ethene(18) created
Micro-moles/Liter
600.0
500.0
400.0
300.0
200.0
100.0
0.0
Baseline
Week 1 - 44% of NZVI
Week 2 - 70% of NZVI
Week 4 - 100% of NZVI
Total Chloro-ethenes
Tetrachloroethene
Trichloroethene
Cis-1,2-Dichloroethene
Trans-1,2-Dichloroethene
Vinyl Chloride
1,1-Dichloroethene
Methane
Ethane
Ethene



VOC Reduction Over Time

WEEK 4

Field Pilot - Preliminary Results

DISCLAIMER: All data is not available and results are just being assessed

- Promising results!
- Downhole dataloggers showed that all wells were being influenced
- Injection well "best" for overall VOC reduction
- NZVI-4 "best" for PCE and TCE reduction
  - Closest downgradient
- cis-DCE produced
  - Need to track breakdown over time
- End breakdown products observed

Next Steps

- Complete analysis of monitoring data
- Work on enhanced biological treatment
- Remedial design
  - Number of injection wells?
  - Well placement?
  - Frequency and timing of injections?
  - NZVI mass requirements?
    - With or without palladium?
  - Use of organic dispersant?
- Construct and implement full-scale system

Nease Site - NZVI Information

- Technical memorandum – later in 2007
  - Results of all tests
  - Recommendations for full scale use
  - Lessons learned
- On the internet
  - http://www.epa.gov/region5/sites/nease/
- Contact me:
  - (312) 886-4699
  - logan.mary@epa.gov

Questions/Comments

Thank You

After viewing the links to additional resources, please complete our online feedback form.

Links to Additional Resources